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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 12

LUNAR SURFACE MAGNETOMETER ANOMALIES

INVESTIGATION OF THE OCCURRENCE OF A "Y" AXIS OFFSET DURING LUNAR DAYS

SSM-13-1399

5.0

AMES RESEARCH CENTER

Moffett Field, California

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JUNE 4, 1970

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5.1 INTRODUCTION

This task is being undertaken to gain an understanding of an anomaly in the magnetometer Y axis data which first appeared on December 22, 1969 after the electronics internal temperature had risen to 60°C prior to noon of the second lunar day. The anomaly is in the form of a large Y axis offset which has reappeared at various times at elevated temperatures during each succeeding lunar day. No success has been attained in exactly simulating the failure using the breadboard magnetometer. The probable location has been generally defined.

Analysis of this anomaly has been separated into the following tasks:

- 1.4 Description of anomaly and conditions of occurrence.
- 5.2 Description of possible causes.
- 5.3 Isolation of most probable cause or causes.
- 5.4 Identification of corrective action and implementation.

Although the magnitude of the offset is to a degree time varying, it has proved to be feasible to subtract it out through application of reverse electrical offset and employment of extra calibrations. For the periods in which it appears, its presence has hampered and slowed analysis of the transmitted data.

5.2 ENGINEERING ANALYSIS AND POSSIBLE CAUSES OF ANOMALY

Insert A

The failure first manifested itself on the 100 gamma range as a fullscale, -100 gamma offset. When the range was changed to the 200 gamma and 400 gamma ranges the offsets were -50% and -25% respectively. When a Flip/Cal was initiated this function was performed correctly showing the proper steps of +25%, +50% and +75%. The 180° flip rotated the offset vector which indicated that the anomalous offset is associated with the sensor channel electronics and is not externally generated. A schematic of the sensor channel electronics is shown in Figure 1. The fact that the percentage amount of the offset changes with range precludes the failure occurring after the input to the prealias filter. That is if the failure occurred after the input to the prealias filter and caused a fullscale offset on the 100 gamma range it would cause a fullscale offset on the 200 gamma and 400 gamma ranges as well.

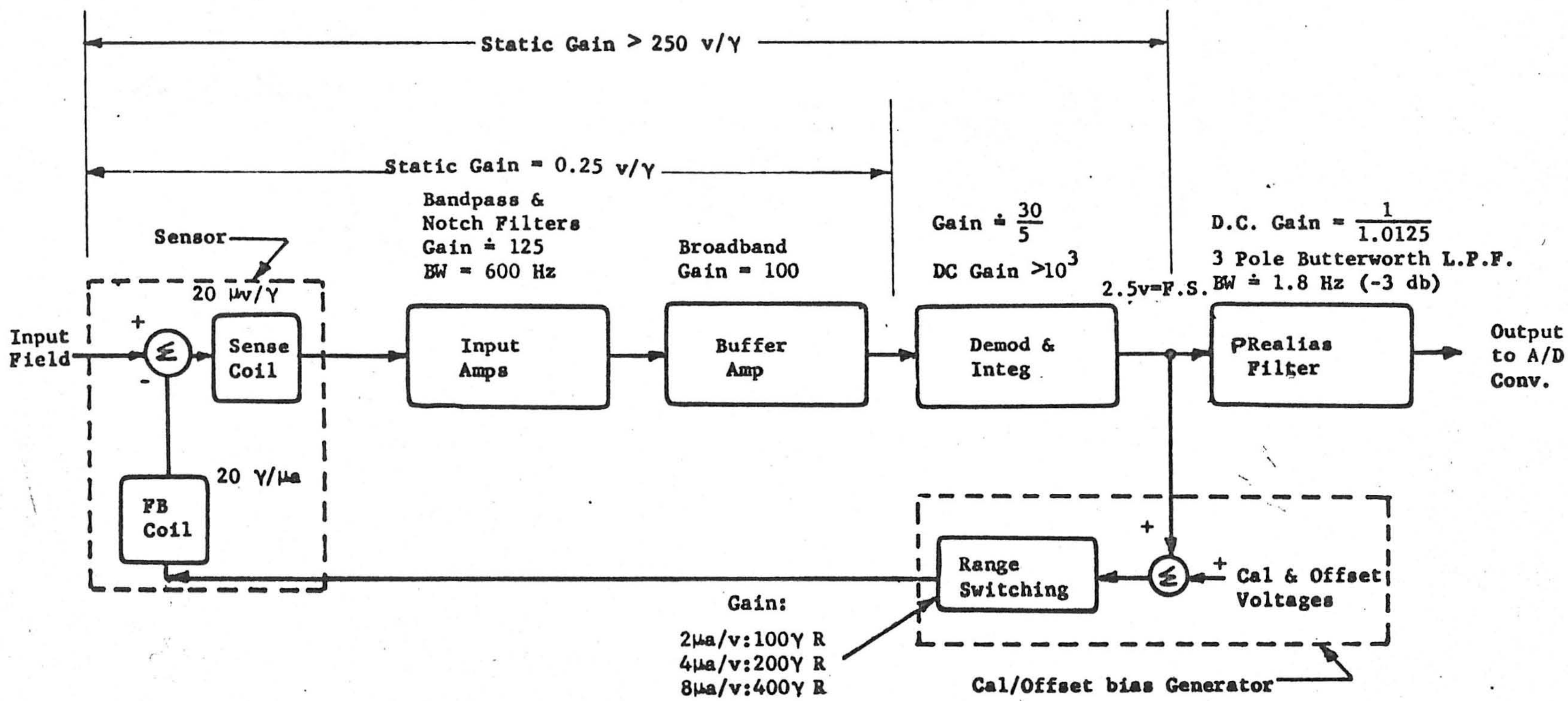
If the failure occurred in the feedback path, in the Cal/Offset ladders or range switching of the Cal/Offset bias generator the offset would appear as a constant percentage of the range. This can be seen from analysis of the simplified schematic shown in Figure 2.

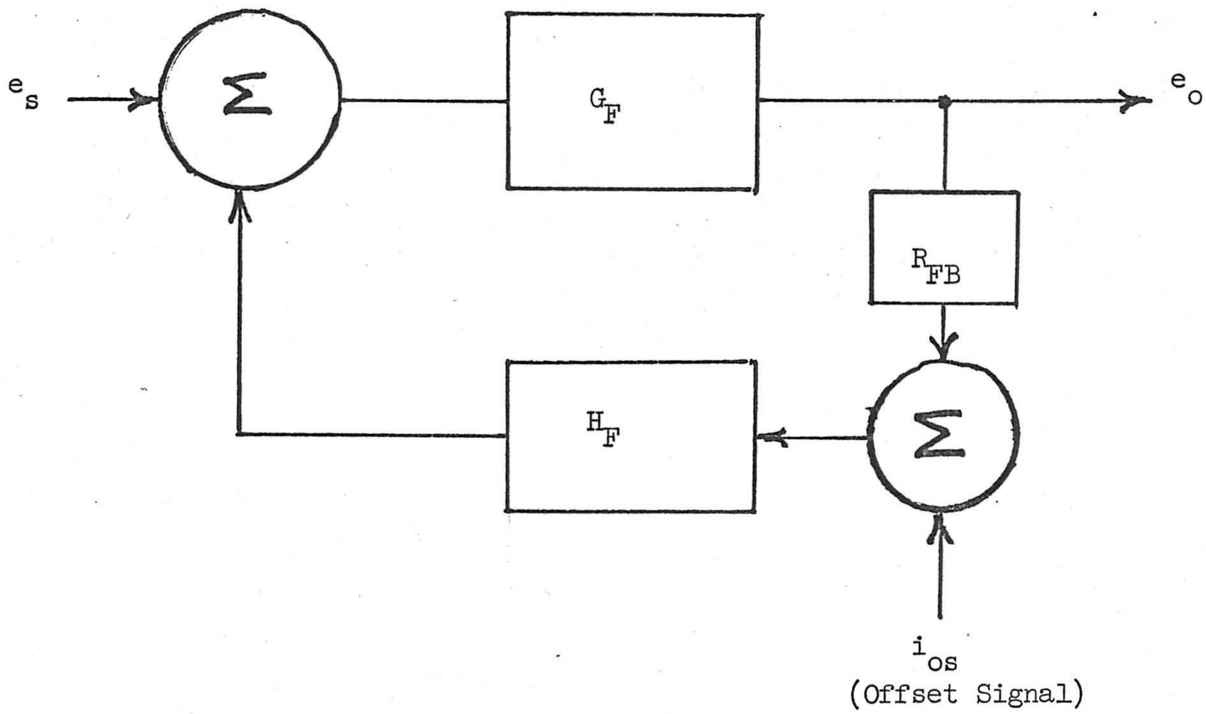
Similarly if the failure were such as to change the feedback H_F then the loop gain given by:

$$\frac{e_o}{e_s} = \frac{G_F}{1 + G_F H_F} \approx \frac{1}{H_F} \text{ for } G_F H_F \gg 1$$

would change and this change could be detected by observing the changes in the Cal raster. Since no change in the Cal raster was observed the failure did not occur in the feedback path.

Fig. 1 SENSOR CHANNEL ELECTRONICS





$$\frac{e_o}{i_{os}} = \frac{G_F H_F}{1 + \frac{G_F H_F}{R_{FB}}} \approx R_{FB}$$

G_F = constant

H_F = Range Change (100 γ, 200 γ, 400 γ)

Figure 2

Insert A

Having eliminated the feedback path as a probable source of the anomaly (by analyses and test), analysis and testing were concentrated on the feedforward path. A summary of the tests conducted and the results are attached. None of the tests conducted on the breadboard duplicated the failure. This is not surprising since the breadboard does not simulate exactly the instrument's physical layout and, in particular does not simulate the interaction of the sensor heaters, position detectors, temperature and various ground returns of the sensor arms and their signals. The failure observed here has not been observed in either the breadboard or any of the flight instruments to date.

5.3 MOST PROBABLE CAUSE

also

At one time it was thought that failure of a conductor in the electrical harness might have caused the failure in the Y channel. As shown in the attached summarization of the simulated tests on the breadboard instrument, various such opens were induced. No results could be obtained which resembled those displayed by LSM #6 on the lunar surface. It is concluded to be unlikely that an open in the electrical harness is the cause of the failure. Nevertheless, steps to improve the reliability of the harness will be reviewed.

Although it has not been possible to achieve on the breadboard instrument the same effects observed on the lunar surface, the most probable cause has been reduced to a thermally induced open circuit in either the Y channel input or buffer amplifiers or in the associated motherboard pin/tab connections. Circuitry within cordwood modules, such as the two modules here considered, has proved to be highly reliable; so also have the great majority of parts used in these modules. Thermal stress resulting in failure of one of the associated motherboard pins is believed to be the most likely cause of the failure. Insert A

5.4 CORRECTIVE ACTION

5.4.1 Steps taken to improve the integrity of motherboard pin connections, to moderate thermal stresses in the instrument, and to enhance reliability through additional thermal test cycles have been described in 3.4 and 3.5. At this time the single most important step which can be taken to prevent future failures such as occurred in this instance is the reduction of temperature stress.

5.4.1.1 Breadboard Verification Testing

The breadboard model of the LSM was put in operation to see if the observed anomaly could be duplicated by inducing failures within the Sensor Electronics. A summary of the tests conducted is attached. Shown on the attachment are the failures induced and the observed effect on the output signal. The philosophy behind the testing was to first try to open those connections which were most likely to cause the observed anomaly and which were most likely to open because of the construction of the flight models, i.e., motherboard pins first, connections internal to the cordwood modules on the top and bottom mylars. Although the analysis indicated that the failure would not have occurred in the feedback path, or after the Demodulator/Integrator this analysis was verified by opening the feedback path and the Demodulator output (Test 12 and 19 for example). The tests then progressed to opening the inputs and outputs of the Input Filter, Input Amplifier, Band Pass Filter, Buffer Amplifier and the Demod/Integrator to see if the anomaly could be duplicated. The inputs and outputs were opened first since the interconnects from module to module are effected by going from the module to a motherboard pin, through a motherboard layer trace to another motherboard pin and into the next cordwood module in the chain. A failure in this portion of the circuitry was more likely to occur than a failure internal to a module. Component failures were simulated by opening leads on the active elements such as the Field Effect Transistors, shunting capacitors with resistors to simulate leaky capacitors, shunting and opening resistors. None of the tests conducted duplicated the failure.

The fact that duplication of the failure by tests on the breadboard is not too surprising in that the breadboard physical layout does not simulate that of the flight models particularly in those portions of the circuitry wherein low level signals or noise sources can be so significant such as the interaction between the sensor signal lines and the lines to the heaters, position detectors, temperature sensors, both signal lines and their returns from the sensor head, through the boom arm to the Sensor Electronics. In the course of the production of the LSMs no failure of the type under discussion has been observed on the breadboard or any of the engineering and flight modules.

Y Channel Offset Tests Summary

	Test Condition	Measured Parameter Offset	Gain γ_o/γ_i	Remarks
1.	Initial	< .88	1	All ranges 20 in tank.
2.	Opened tapped Coil Gd on L3 of Input Filter 39-175420	Full Scale Positive	0	Outside range of GSE
3.	Opened Feedback Winding Shield	< .88 γ	1	No effect
4.	Opened L1 - Input Filter 39-175420	1 γ	1	
5.	Opened L2 - Input Filter 39-175420	−2 γ	1	
6.	Opened Band Pass Filter L1 39-175421	-1.6 γ	1	
7.	Removed Band Pass Filter 39-175421, 39-175417	Full Scale	0	
8.	Opened R_5 = 470 Ω Demodulator 39-175428	Full Scale Negative	0	Turns off Demodulator
9.	.01 μfd Capacitor Grounded 39-175428	- .75 γ	1	
10.	Opened C_2 - Demod 39-175428	.2 γ	1	

11.	Opened Integrating Capacitor - Demod 39-175428	-8 γ	.25	Output very noisy
12.	Opened - 7V Reference to Summing Network 39-175458	+80 γ	1	75% Offset
	100 Range	-81.6 γ	1	0% Offset
	200 Range	-163.2 γ	1	0% Offset
	400 Range	-362 γ	1	0% Offset
13.	Opened Pin M Control of Q1 FET 39-175428	Could not be measured		System went into oscillation
14.	Opened R3 (68KΩ) Input Filter 39-175420	< .4 γ	1	
15.	Opened R2 (68KΩ) 39-175420	< .4 γ	1	
16.	Opened PNP Emitter Res. 39-175420	< .4 γ	1	
17.	Opened Q1 Emitter Input Filter 39-175417	.45 γ	1	
18.	Opened Q2 Emitter Input Filter 39-175417	.2 γ	1	
19.	Opened C_7 Capacitor L4 Ground Band Pass Filter 39-175417	- .5 γ	1	
20.	Demodulator Input Opened 39-175424 Demod Output Opened	300 MV p-p 90 µs period ~ 12.5 KHZ		Quadrature

21.	10 KΩ Resistor Placed across C_7 Input Amplifier 39-175417	-2 γ	1	Simulate leaky capacitor
22.	Open Triming Capacitor C8 on L1 Band Pass Filter 39-175421	Full Scale		Could not get signal off full scale with GSE

5.4.2 Arm Electrical Harness

On January 12, 1970 during calibration of LSM #4 at GSFC, the Y channel read saturation on all ranges when the Y arm was fully deployed. Subsequently it was determined that an open existed in the E-2 sensor lead. Upon removal of the cable from the Y arm, some deformation of the Y arm individual wire insulation was observed at the arm elbow joint (see attached ref. memo SSM-13-1379 dtd. 3/11/70) and all strands of the above wire had parted. Some damage to shields was also evident.

The examination of the individual wires described in SSM-13-1379 revealed no broken strands in the seven-strand conductors, other than the entirely failed conductor in the Y arm. Many instances of failed strands in the shields were observed, however. Where instrument usage is known to have been extensive, the condition of the shields must be assumed from this study to have deteriorated. This alone is considered to create a clear need for cable replacement in the LSM #3 instrument.

It does not appear likely that any of the LSM #6 anomalies could have been caused by failures of the conductors within the sensor arm electrical harnesses. Nevertheless steps have been taken to preclude the possibiluty of this sort of failure again occurring in a flight instrument.

Because of the damage evident in the Y arm harness and the history of many flexures of the arms of this instrument, the decision was made to replace all three harnesses in LSM #4 and to grossly reduce arm flexures of all instruments in the future. (Ref. Philco-Ford RMR 57710). Because LSM #7 had had much less use, arm cables in this instrument were not changed.

The history of LSM #3, about to be refurbished as a back-up instrument for Apollo 16, indicates extensive testing and the decision has been made to remove the harnesses from the arms of this instrument also. The harness construction is being studied to determine whether any improvements can be introduced which will ameliorate the flexure stresses in the bundle at the elbow joint.

Using harnesses obtained from LSM #4 and #7, tests were conducted to determine the number of times the electrical harness can be flexed 180° at the mid-arm elbow joint without failure of the conductors or shields. Six lengths of harness were tested, four to 700 cycles and two to 1000 cycles. The harnesses were flexed per the attached procedure 180° around a 7/16" radius bar, simulating the approximate bend radius within the LSM arm itself. No failures of conductors or shields were observed. A limit of 100 flexures has been placed on the number of times the arms of flight instruments can be folded and a requirement has been placed on test crews to record in the instrument log book each time the arms are stowed.

OPTIONAL FORM NO. 10
5010-104

UNITED STATES GOVERNMENT

Memorandum

TO : File DATE: March 11, 1970

FROM : J. S. Keeler Ref: SSM-13-1379

SUBJECT: LSM #4 X and Z Arm Cable Disassembly

1. LSM #4 X and Z arm cables were disassembled this date to determine whether any wires were undergoing damage of a nature similar to that reported in the Y arm cable failure analysis by Philco-Ford. Each cable has three double shielded single conductors and six shielded pairs.

2. The outer insulation and shield were removed from all eighteen wires or pairs for approximately three inches centered at the arm elbow joint. The insulation was deformed in some instances, particularly on those wires located in the bundle at the inner radius of the bend at the elbow. None were deformed as badly as the wire which had broken in the Y arm. Of the 18 shields, all but two had one or more broken strands at the bend. Many had one or two strands broken, a few had three or four, and in three, half or more of the strands had broken.

3. The insulation was then stripped from some of the pairs and the insulation, inner shield, and inner insulation stripped from some of the single conductor wires. (All wires were seven strand). In all cases the wires chosen were those which appeared to be the most badly deformed. The inner shields were found to be undamaged and no broken strands were found in the conductors. It is concluded that for some unknown reason, bending deformations and stresses in the Y arm cable were more severe.

John Keeler

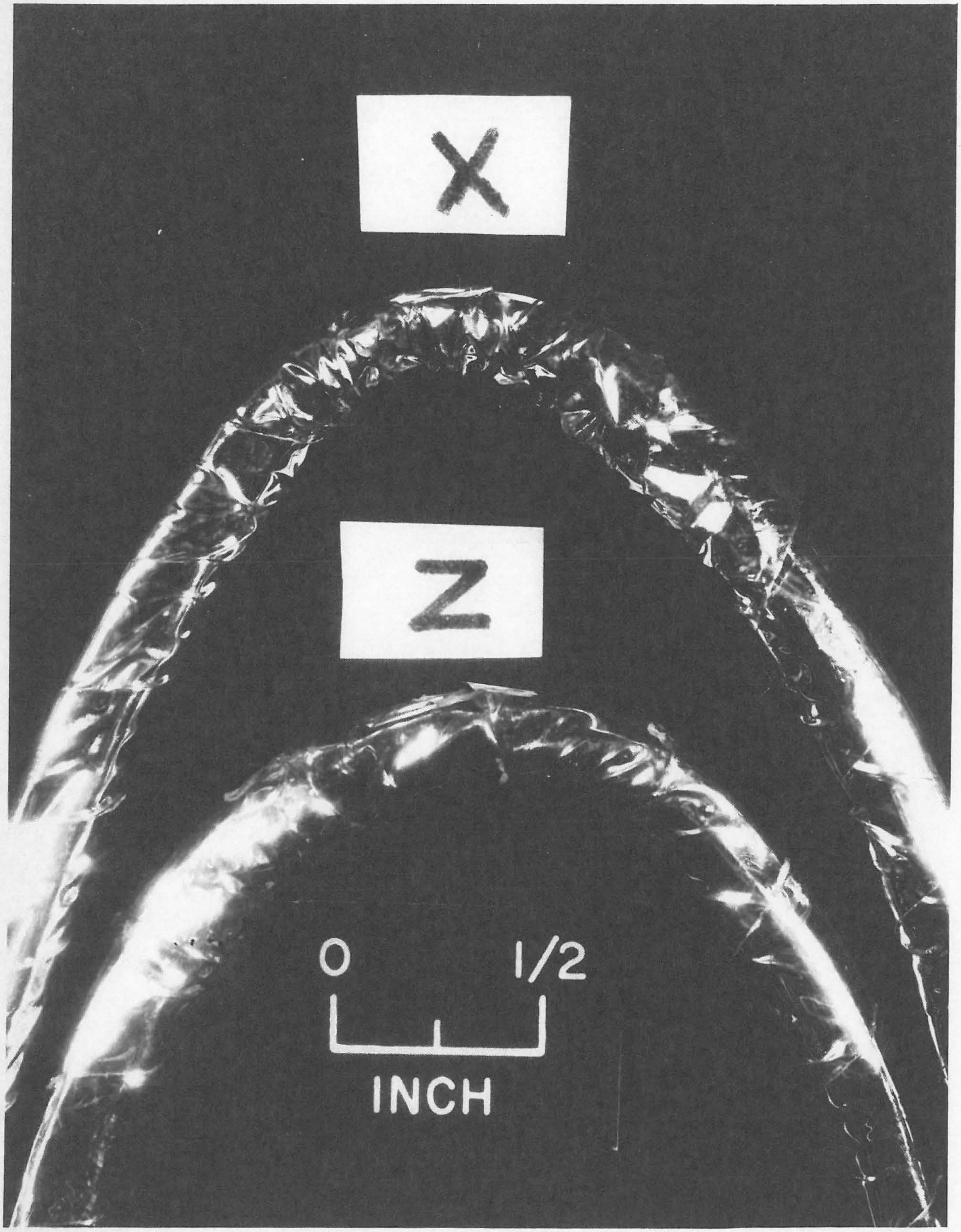
John S. Keeler
LSM Experiment Manager

Enclosures (4)
Photos - List attached

LUNAR SURFACE MAGNETOMETER # 4

X AND Z ARM CABLE PHOTOGRAPHS

A 70-1433	X and Z Arm Cables - Folded Position
A 70-1434	X and Z Arm Cables - Unfolded Position
A 70-1435	Z Arm Cable - Tape Wrapping Removed
A 70-1436	X Arm Cable - Tape Wrapping Removed



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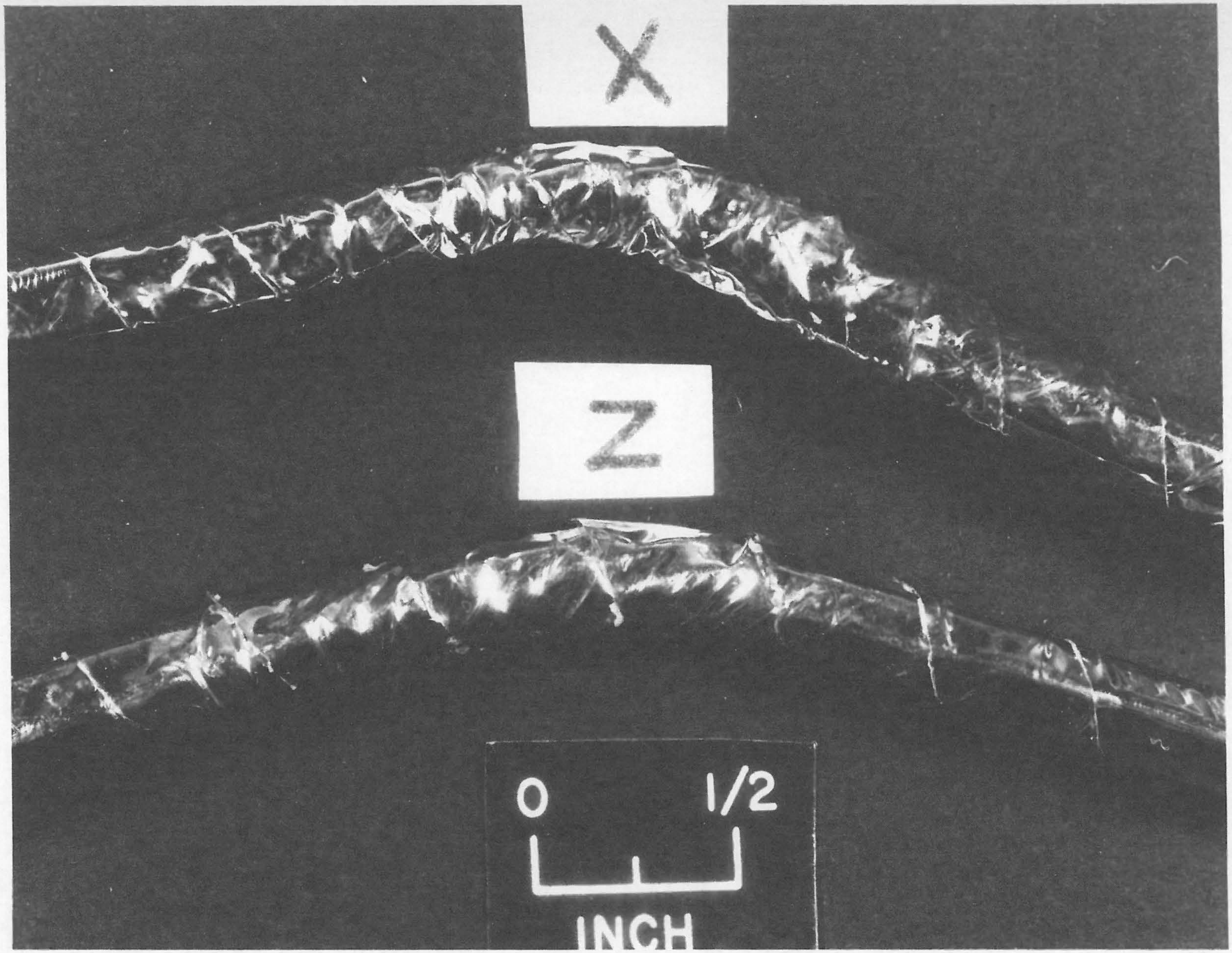

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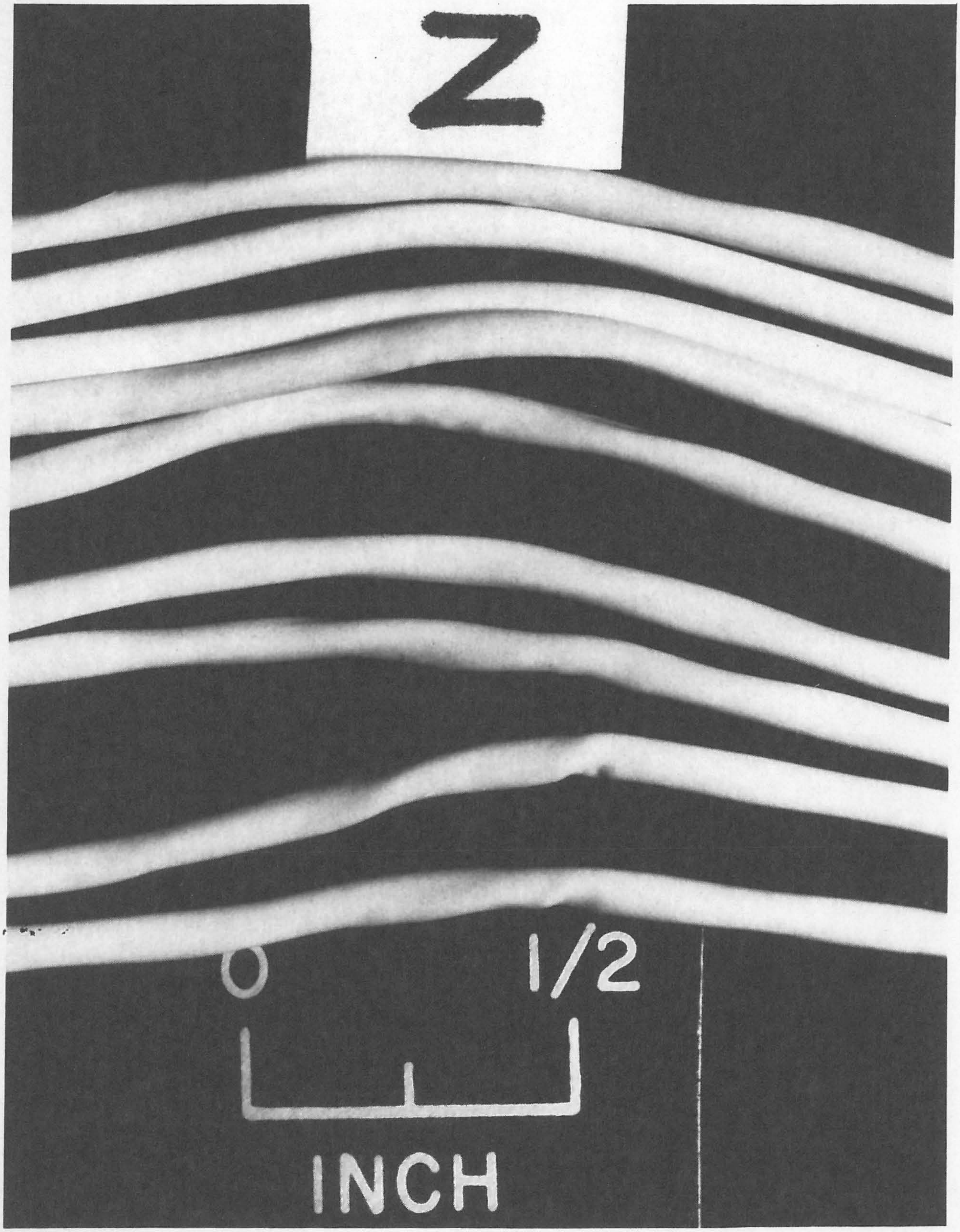
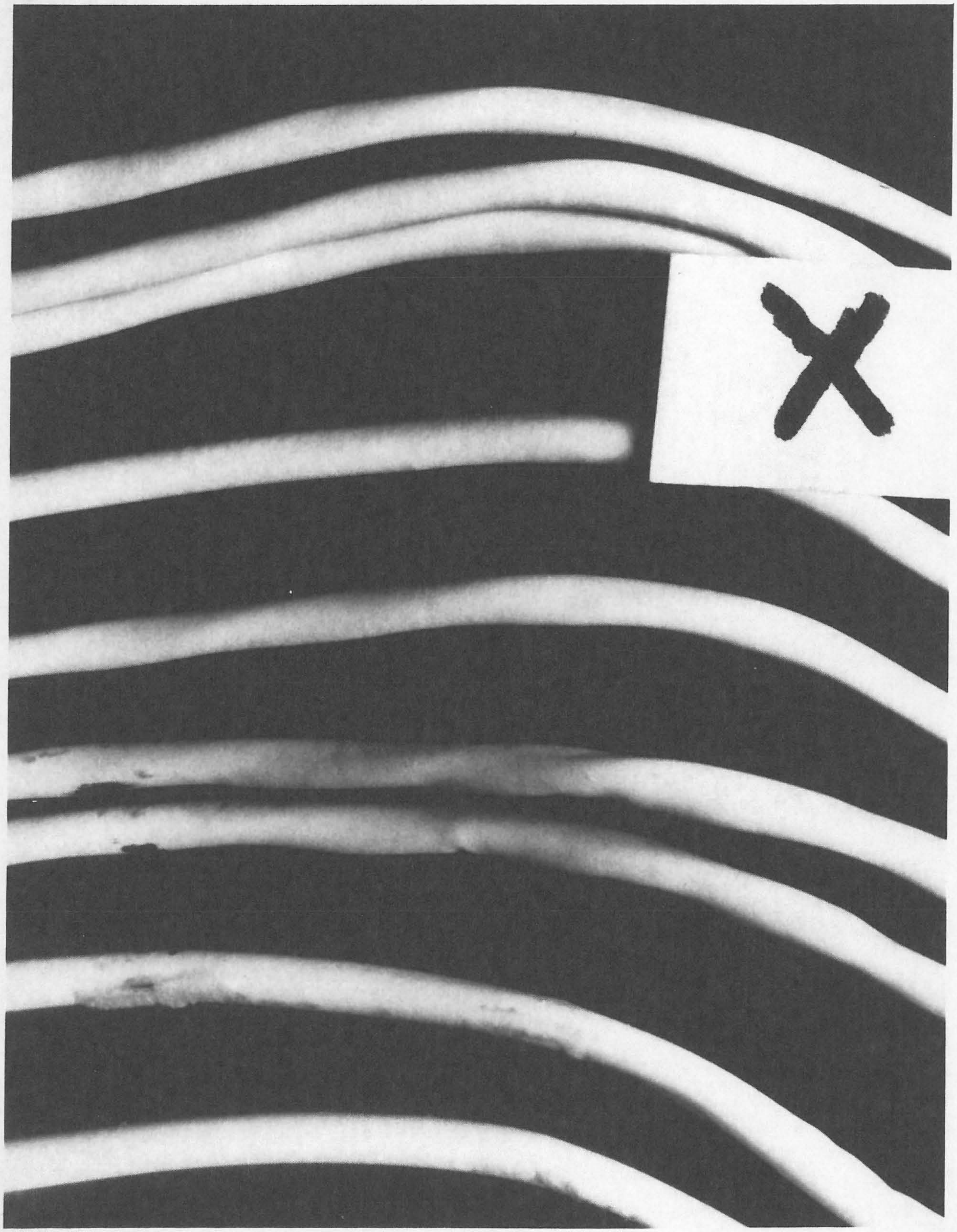


A70-1435



A70-1436

LSM ELECTRICAL HARNESS

FLEXURE TEST PROCEDURE

	Op.	Date
1. Preparation:		
a. Assure that gold tape wrapping is configured identically to harness as installed in LSM arm.	JK	May 26, '70
b. Secure ends of harness to assure that no slippage at ends occurs between individual leads.	JK	5/26
c. Tie all conductors and shields together electrically at one end of harness. Bare conductors and shields at other end, taking care to assure that conductors and shields are not in electrical contact.	JK	5/26
2. Test:		
a. Flex each of four harnesses at one location 50 times around a 7/16" radius.	JK	5/26
b. Check conductors and shields for continuity. During each check flex harness slightly.	JK	5/26
c. Record and identify on harness any broken conductors or shields.	JK	5/26
d. Repeat until two conductors have broken on each harness.	JK	5/26

e. Test Results

Harness A failures at None ~~cycles~~ @ 700 cycles

Harness B failures at None ~~cycles~~ @ 700 cycles

Harness C failures at None ~~cycles~~ @ 700 cycles

Harness D failures at None ~~cycles~~ @ 700 cycles

Harness E - no failures @ 1000 cycles

Harness F - " " " " "

JRK